mention now one simple way which I illustrated by experiment at the meeting referred to. It is fairly well recognized that sheet lightning is the reflection of a flash on a cloud, for example; but if there happens to be the presence of a cloud with a small opening in it somewhere between the actual flash and the distant surface of clouds, then, instead of "sheet" lightning appearing on the latter, there will be "projection" lightning—that is, the image of the flash, whose shape will depend upon the shape of the cloud on which it is cast.

In speaking of zigzag representations of lightning flashes, it is important to make some distinction between the artistic zigzag and a common pictorial type such as is seen on the covers of electrical books, in dissolving views, in scenic effects, and even in street advertisements. It is hardly fair to saddle the artists with the latter class. A good specimen of an artistic zigzag flash, and one which shows an observance of nature, can be seen in Wilson's famous picture of "Celadon and Amelia."

It certainly seems at first sight strange that the "projection" flash should not be included in the photographs of lightning flashes. Its non-appearance may be due (1) to the photographic plates not being sufficiently sensitive to register a flash of diminished brilliancy, for the projected image of any source of light has not the same intensity as the source itself. (2) The "projection" flash being of rarer occurrence, the number of photographs yet taken may not have included it. If the type is rarer, it may be objected that it is not likely that artists would generally depict a rare type in preference to the more common one; but the less dazzling nature of the "projection" would be sufficient to account for its adoption, rendering the form of the flash more distinct to the average eye. To take an illustration, if an electric arc light is suddenly flashed before our eyes, we fail to distinguish the form of the white-hot carbon points, but if its image were flashed upon a screen, their form would be distinctly visible.

It is worthy of note that some painters have chosen to represent other types than what I have termed the "projection" flash. See Turner's "Stonehenge," where "streaming" lightning is pictured. ERIC STUART BRUCE.

10 Observatory Avenue, Kensington, W., June 16.

### The Bagshot Beds of Essex.

In the second part of the paper on the Westleton beds, by Prof. Prestwich, recently published in the *Quarterly Journal of the Geological Society* (vol. xlvi. p. 152), a section of the Brentwood railway cutting is given, which is, if possible, of more interest from the Eocene beds described than from its bearing on the questions dealt with in the paper.

Reading the new section together with what we already know, we get the following succession of beds at Brentwood:—

(1) *Pebble beds,* capping the plateau up to 15 feet thick.

(2) *Bagshot beds,* about 50 feet, consisting of—

(*a*) Yellow or white sands (bed 6 of Mr. Whitaker's section, "Geology of London," i. 274).

(*b*) The green sands and clays *with fossils* of the railway cutting.

(*c*) Yellow sand with seams of clay of the railway cutting.

(3) *London clay,* about 435 feet, the upper part consisting of dark grey clay, with one or more beds of loam and yellow sand, the so-called "passage beds" exposed in the brick-fields near the station.

The fossils which Mr. Herries and I found near Frierning (Whitaker, "Geology of London," i. 276) came from white sand probably answering to bed 2*a*.

This section seems to show pretty clearly that the Bagshot beds of Brentwood are more nearly allied to the marine Bracklesham (Middle Bagshot) series than to the Lower Bagshots of the Bagshot Heath district, which are probably freshwater. If this be so, the masses of pebbles which overlie them may well be the remains of the pebble beds which so often mark the base of the Upper Bagshot (Barton) beds, and the parallel drawn by Mr. Herries and myself between the pebbles which cap the Warley and Brentwood plateau in Essex and those which cap Hook Heath and other hills in the Bagshot district becomes the more marked (Proc. Geol. Assoc., vol. xi. pp. 13, 16, 20).

1 Hare Court, Temple. HORACE W. MONCKTON.

### Electro-Magnetic Repulsion.

THOSE who have not the means of showing the striking effects produced by Prof. Elihu Thomson may be glad to know a simple illustration of the same principles.

A top consists of a soft iron disk with a brass axis put through it. A small magnet is held over the edge whilst spinning; each elementary sector as it moves up to and away from the poles of the magnet has currents induced which are repelled by the magnet; as the rotation dies out, the currents at a certain point become too feeble to overcome the attraction of the soft iron by the magnet. I bought the top two or three years back of M. Manet, 49 Rue Lourmel, Paris. W. B. CROFT.

Winchester College, June 21.

### A Remarkable Appearance in the Sky.

THERE was an appearance in the sky last night, so remarkable that I am tempted to describe it, in case, our situation being high, it should have been better seen here than elsewhere. Along the horizon, from north to about north-east, a faint bank of cloud extended, above which was a space of light like that of the early dawn or of the rising moon. There was no quivering, or shooting upwards of rays, as in the ordinary northern lights; the light was steady, white tending to yellow, brighter at the lower part. Above it hung a purplish haze, through which the stars shone brightly, and occasional strips of dark cloud. It did not happen to be observed till 10.30 p.m., and it was hardly altered at 1.30 a.m., when it was still bright enough to mark the window-frame through a white blind, like moonlight. Besides the position, the fact of a solar eclipse occurring that day proved the moon to have nothing to do with it.

Sussex, June 18. M. E.

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## *PROBLEMS IN THE PHYSICS OF AN ELECTRIC LAMP.*[1]

### I.

MORE than eighty years ago Sir Humphry Davy provided the terminal wires of his great battery of 2000 pairs of plates with rods of carbon, and, bringing their extremities in contact, obtained for the first time a brilliant display of the electric arc.[2] The years that have fled away since that time have seen all the marvellous developments of electro-magnetic engineering, have placed in our possession the electric glow-lamp, and brought the art of electrical illumination to a condition in which it progresses each year with giant strides. In addition to the importance attaching to their ever-increasing industrial use, there are many questions of purely scientific interest which present themselves to our minds when we proceed to examine the actions that take place when a carbon conductor is rendered incandescent in a high vacuum, or when an electric arc is formed between two carbon poles. It is to a very few of these physical problems that I desire to direct your attention to-night, but more especially to one which is particularly interesting from the bearing which it has on the general nature of electric discharge.

We know as a very familiar fact that if we attempt to raise the temperature of a carbon conductor inclosed in a vacuum beyond a certain limit, not far removed from the melting-point of platinum, the carbon begins to volatilize with great rapidity. If an electric glow-lamp has passed through its carbon more than a certain strength of current, the glass bulb speedily becomes darkened by a deposit of this volatilized carbon condensed upon it; and experience shows us that we cannot raise the temperature of that carbon beyond a definite point without causing this waste of the conductor to become very rapid. In the highly rarefied atmosphere within the bulb of a glow-lamp, the carbon, when at its normal incandescence, must be considered to be projecting off molecules of carbon in all directions, partly in virtue of purely thermal actions, but probably also in consequence of certain electrical effects to be presently discussed. This scattering of the material of the carbon conductor takes place with disadvantageous rapidity from an industrial point of view at and beyond a certain temperature,[1] but it exists as well at much lower temperatures than that which is found to determine the practical limit of durability. A curious appearance is found in many incandescent lamps which have been "over-run," which shows us that this projection of carbon molecules from the hot conductor is not, perhaps, best described by calling it a vaporization of its substance, but that the surface molecules are shot off in straight lines, and that they reach the glass envelope without being hindered to any great extent by the molecules of the residual air.

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[1] Friday Evening Discourse delivered at the Royal Institution by Prof. J. A. Fleming, M.A., D.Sc., on February 14, 1890.

[2] Sir Humphry Davy laid a request before the managers of the Royal Institution on July 11, 1808, that they would set on foot a subscription for the purchase of a large galvanic battery. The result of this suggestion was that a galvanic battery of 2000 pairs of copper and zinc plates was set up in the Royal Institution, and one of the earliest experiments performed with it was the production of the electric arc between carbon poles, on a large scale. It is probable, however, that Davy had produced the light on a small scale some six years before, and, according to Quetelet, Curtet observed the arc between carbon points in 1802. See Dr. Paris's "Life of Sir H. Davy."

If an electric current is passed through an otherwise uniform carbon conductor, which possesses at any one place a specific resistance higher than that of the remaining portion, the current, in accordance with a well-known law, there develops a higher temperature, and the molecular scattering at that spot may in consequence be greatly exaggerated. It may be that the detrition of the conductor at that locality will be so great as to cut it through after a very short time. When the carbon has the form of a simple horseshoe loop, and when this molecular scattering takes place from some point in the middle of one branch, the molecular projection makes itself evident by producing a "molecular shadow" of the other leg upon the interior of the glass. I will project upon the screen an image of the carbon horse-shoe loop taken from an old glow-lamp, and you will be able to see that the filament has been cut through at one place. At that position some minute congenital defect caused the carbon to have a higher resistance, the temperature at that point when it was in use became excessive, and an intensified molecular scattering took place from that locality. On examining the glass bulb from which it was taken, we find that the glass has been everywhere darkened by a deposit of the scattered carbon except along one narrow line (see Fig. 1), and that line is in the plane of the carbon loop and on the side opposite to the point of rupture of the filament.[2]

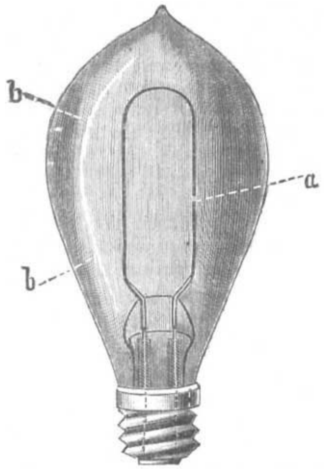

FIG. 1.—Glow-lamp, having the glass bulb blackened by deposit of carbon, showing the molecular scattering which has taken place from the point *a* on the filament, and the shadow or line of no deposit produced at *b*.

I may illustrate to you, by a very simple experiment, the way in which that "shadow" has been formed. Here is a ∩-shaped rod: this shall represent the carbon conductor in the lamp; this sheet of cardboard placed behind it, the side of the glass receiver. I have affixed a little spray-producer to one side of the loop, and from that point blow out a spray of inky water. Consider the ink spray to represent the carbon atoms shot off from the overheated spot. We see that the cardboard is bespattered on all points except along one line where it is sheltered by the opposite side of the loop. We have thus produced a "spray shadow" on the board (Fig. 2). The existence of these molecular shadows in incandescent lamps leads us therefore to recognize that the carbon atoms must be shot off in straight lines, or else obviously no such sharp shadow could thus be formed. This phenomenon confirms in a very beautiful manner the deductions of the kinetic theory of gases. I may remind you that at the ordinary temperature and pressure the mean free path of a molecule of air is deduced to be about four one-millionths of an inch. This is the average distance which such a gaseous molecule moves over before meeting with a collision against a neighbour which changes the direction of its path. Let the air be rarefied, as in these bulbs, to something like a millionth of the ordinary atmospheric pressure, and the mean free path is increased to several inches. The space within the bulb—though from one point of view densely populated with molecules of residual air—is yet, as a fact, in such a condition of rarefaction that a carbon molecule projected from the conductor can move over a distance of three or four inches on an average without meeting with interference by collision with another molecule, and the facts revealed to us by these shadows show that this must be the case. I have also at hand some Edison lamps in which these "molecular shadows" are finely shown, but in these cases the deposit on the interior of the bulb is not carbon but copper, because the molecular scattering has here taken place by excessive temperature developed at the copper clamps by which the carbon filament is attached to the platinum wires. The theory, however, is the same. The deposit of copper shows a fine green colour by transmitted light in the thinner portions. One curious lamp also before me had by an accident an aluminium plate volatilized within the bulb. The glass receiver has in consequence been covered with a mirror-like deposit of aluminium, which on the thinner portions shows a fine blue colour by transmitted light, and a silvery lustre by reflected light. This lamp also shows a fine "molecular shadow."

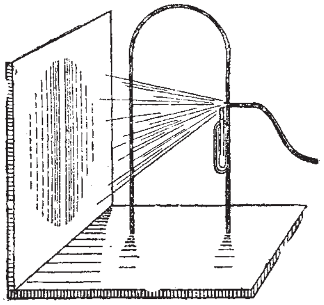

FIG. 2.—"Spray shadow" of a rod thrown on cardboard screen to illustrate formation of "molecular shadow" in glow-lamps.

These facts prepare us to accept the view that when a glow-lamp is in operation the highly rarefied residual air in the interior of the bulb is being traversed in all directions by multitudinous carbon atoms projected off from the incandescent carbon conductor. I now wish to pass in review before you some facts which indicate that these carbon atoms carry with them electric charges, and that they are charged, if at all, with *negative electricity*.

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[1] When the rate of expenditure of energy in the carbon conductor is raised until it reaches a value of about 500 watts, or 360 foot-pounds per second per square inch of radiative surface, a limit of useful temperature has been reached for economical working, under the usual present conditions of steam-engine-driven dynamos and modern glow-lamps.

[2] The writer desires to express his indebtedness to the editor of the *Electrician* for the loan of the blocks illustrating this abstract.

I may preface all by saying that much of what I have to show you will be seen to be closely related to the phenomena studied by Mr. Crookes in his splendid and classical researches on radiant matter. Our starting-point for this purpose is a discovery made by Mr. Edison in 1884, and which received careful examination at the hands of Mr. Preece in the following year,[1] and by myself more recently. Here is the initial experiment. A glow-lamp having the usual horseshoe-shaped carbon (see Fig. 3) has a metal plate held on a platinum wire sealed through the glass bulb. This plate is so fixed that it stands up between the two sides of the carbon arch without touching either of them. We shall illuminate the lamp by a continuous current of electricity, and for brevity's sake speak of that half of the loop of carbon on the side by which the current enters it as the positive leg, and the other half of the loop as the negative leg. The diagram in Fig. 4 shows the position of the plate with respect to the carbon loop. There is a distance of half an inch, or in some cases many inches, between either leg of the carbon and this middle plate. Setting the lamp in action, I connect a sensitive galvanometer between the middle plate and the *negative terminal* of the lamp, and you see that there is no current passing through the instrument. If, however, I connect the terminals of my galvanometer to the middle plate and to the *positive electrode* of the lamp, we find a current of some milliamperes is passing through it. The diagrams in Fig. 5 show the mode of connection of the galvanometer in the two cases. This effect, which is often spoken of as the "Edison effect," clearly indicates that an insulated plate so placed in the vacuum of a lamp in action is brought down to the same potential or electrical state as the negative electrode of the carbon loop. On examining the direction of the current through the galvanometer we find that it is equivalent to a flow of negative electricity taking place through it *from* the middle plate *to* the positive electrode of the lamp. A consideration of this fact shows us that there must be some way by which negative electricity gets across the vacuous space from the negative leg of the carbon to the metal plate, whilst at the same time a negative charge cannot pass from the metal plate across to the positive leg. Before I pass away from this initial experiment, I should like to call your attention to a curious effect at the moment when the lamp is extinguished. Connecting the galvanometer as at first, between the middle plate and the negative electrode of the lamp, we notice that though made highly sensitive the galvanometer indicates no current flowing through it whilst the lamp is in action. Switching off the current from the lamp produces, as you see, a violent kick or deflection of the galvanometer, indicating a sudden rush of current through it.

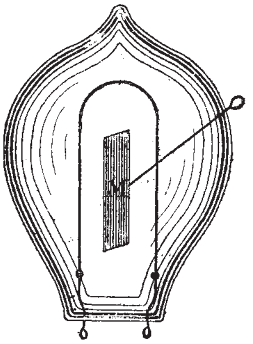

FIG. 3.—Glow-lamp having insulated metal middle plate M sealed into bulb to exhibit "Edison effect."

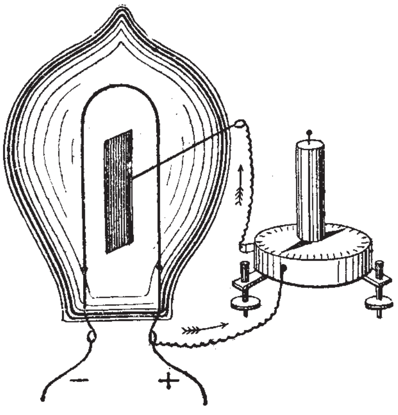

FIG. 4.—Sensitive galvanometer connected between the middle plate and positive electrode of a glow-lamp, showing current flowing through it when the lamp is in action ("Edison effect").

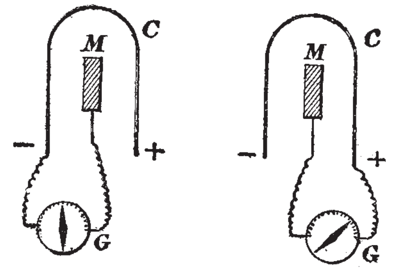

FIG. 5.—Mode of connection of galvanometer G to middle plate M and carbon horseshoe-shaped conductor C in the experiment of the "Edison effect."

In endeavouring to ascertain further facts about this effect one of the experiments which early suggested itself was one directed to determine the relative effects of different portions of the carbon conductor. Here is a lamp (see Fig. 6) in which one leg of the carbon horseshoe has been inclosed in a glass tube of the size of a quill, which shuts in one-half of the carbon. The bulb contains, as before, an insulated middle plate. If we pass the actuating current through this lamp in such a direction that the covered or sheathed leg is the *positive* leg, we find the effect existing as before. A galvanometer connected between the plate and positive terminal of the lamp yields a strong current, whilst if connected between the negative terminal and the middle plate there is no current at all. Let us, however, reverse the current

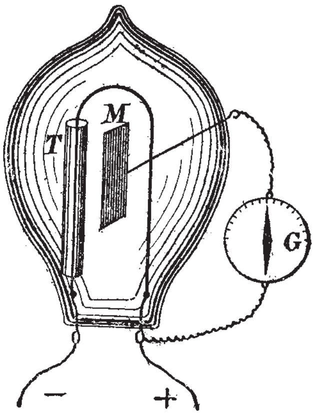

FIG. 6.—Glow-lamp having negative leg of carbon inclosed in glass tube T, the "Edison effect" thereby being annulled or greatly diminished.

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[1] Mr. Preece's interesting paper on this subject is published in the "Proceedings" of the Royal Society for 1885, p. 219. See also the *Electrician*, April 4, 1885, p. 436.

through the lamp so that the shielded or inclosed leg is now the negative one, and the galvanometer is able to detect no current, whether connected in one way or the other. We establish, therefore, the conclusion that it is the negative leg of the carbon loop which is the active agent in the production of this "Edison effect," and that if it is inclosed in a tube of either glass or metal, no current is found flowing in a galvanometer connected between the positive terminal of the lamp and this middle collecting plate.

Another experiment which confirms this view is as follows:—This lamp (see Fig. 7) has a middle plate, which is provided with a little mica flap or shutter on one side of it. When the lamp is held upright the mica shield falls over and covers one side of the plate, but when it is held in a horizontal position the mica shield falls away from the front of the plate and exposes it. Using this lamp as before, we find that when the positive leg of the carbon loop is opposite to the shielded face of the plate, we get the "Edison effect" as before in any position of the lamp. Reversing the lamp current and making the same leg the *negative* one, we find that when the lamp is so held the metal plate is shielded by the interposition of the mica, and the galvanometer current is very much less than when the shield is shaken on one side and the plate exposed fully to the negative leg.

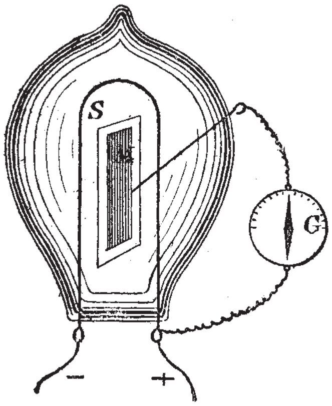

FIG. 7.—Glow-lamp having mica shield S interposable between middle plate M and negative leg of carbon, thereby diminishing the "Edison effect."

(*To be continued.*)

## SOME EXPERIMENTS ON FEEDING FISHES WITH NUDIBRANCHS.

WITH the view of testing the theory that the remarkable shapes and colours of Nudibranchs are either of a protective or of a warning nature,[1] and are definitely related to the edibility or the reverse of the animals, I have been offering lately various kinds of Nudibranchs to the fishes in the aquarium of the Liverpool Free Public Museum,[2] and have carefully noted the result of each trial.

Although these experiments will have to be repeated, and additional evidence accumulated, still it may be interesting to other biologists working on similar lines to have this account of the inquiry, in its present stage, laid before them, and I need scarcely say that I would be glad of any suggestions which would be useful in future investigations.

Most of the experiments were made in three large fish-tanks, which may be called A, B, and C. A and B are rectangular slate and plate-glass wall-tanks, lit from the top, measuring $7\frac{1}{2}$ feet long, $5\frac{1}{4}$ feet wide, and $3\frac{1}{4}$ feet high. A has a gravel bottom, and contains about 20 very healthy and active shannies (*Blennius pholis*) obtained from the Menai Straits; while B has a sandy floor, and is devoted to flat-fish. It contains a considerable number of soles and plaice, a few small thornback rays, turbot, and brill, and on one of the occasions had some young cod. The average size of these flat-fish is 6 inches in length, and there are over 60 of them in the tank. Both A and B have some rock-work. C is an octagonal centre-tank with a sandy bottom, measuring $4\frac{1}{2}$ feet in diameter, and 17 inches in depth. It contains various small fishes, viz. bullhead, goldsinny, pogge, gemmeous dragonet, five bearded rockling, viper-weever, and young cod.

All these fishes are apparently in a healthy condition, and some of them have been living undisturbed in their tanks for periods varying up to four years. They are usually fed upon mussels, cockles, and occasionally worms, which are thrown in at the top of the tank and allowed to sink through the water. Such food-matters are usually seen at once, and eagerly pounced upon and eaten during their descent. I adopted the same plan in putting most of the Nudibranchs into the tanks, and as the fishes were not fed on the days I intended to experiment with them, and had usually been fasting for 24 hours when I began, they may be regarded as being unusually eager to seize any object dropped into the water. At the beginning and again at the end of each day's experiments, we threw a couple of cockles or mussels into the tanks, and found that they were at once caught and bolted in the usual manner.

I. *October* 29, 1889. [A supply of *Doris*[1] *bilamellata* was obtained from the rocks at New Brighton.]

TANK A.—*Doris.*

(1) Seized, when falling, by a shanny, and taken at once to dark corner.

(2) Seized and at once rejected, seized by another shanny and at once rejected, seized by a third and rejected, then allowed to lie on bottom of tank.

(3) Seized and rejected by two fish in rapid succession, then seized by third and taken to dark corner.

(4) Seized and rejected by first fish, taken to dark corner by second.

(5) Seized and rejected by three fish in rapid succession, and then left.

TANK B.—*Doris.*

(1) Seized and rejected in rapid succession by a turbot, a sole, another sole, and a plaice, and then left lying on the sand.

TANK C.—*Doris.*

(1) Seized and rejected by a goldsinny, tried again by same and again rejected, then left.

(2) Seized and rejected by a bullhead and by a dragonet in rapid succession, and then left.

Finally, another *Doris* was dropped gently into a fourth tank containing a conger eel, so as to fall in front of its nose; but although the fish passed close to the Nudibranch several times while under observation, it apparently took no notice of it.

From these nine experiments it seems probable that *Doris bilamellata* is distasteful to at least most of these eight kinds of fishes tried. This was an unexpected result, as *Doris* has no stinging apparatus, and certainly seems to be protectively coloured. The distastefulness may be due to the spicules in the skin or to the abundant mucus covering the body.

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[1] *Quart. Journ. Microsc. Sci.*, vol. xxxi. p. 41.

[2] With the kind permission and assistance of Mr. T. J. Moore, the curator, and his assistants, who were present at all the experiments.

[1] I use throughout this article the old well-known generic names *Doris* and *Eolis*, instead of the modern genera, only known to specialists, in which the species I am dealing with have been placed. No possible confusion can arise from doing so.